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PRIMER OF GEOMETRY

AN EASY INTRODUCTION
TO
THE PROPOSITIONS OF EUCLID

BY

FRANCIS CUTHBERTSON, M.A., LL.D.

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CITY OF LONDON SCHOOL

WILLIAM BLACKWOOD AND SONS
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PREFACE.

WHILST many of the Propositions of Euclid are very easy, there are others equally hard for the student to understand; moreover, they are not graduated according to their difficulty. Thus the Fifth Proposition of his First Book is invariably found to be a greater stumbling-block than most of those which follow. Now the earliest time at which the study of the Elements can be commenced is necessarily fixed by the difficult parts. Accordingly, inasmuch as those whose capacity is considerably below the limit thus indicated could master the easy portions, it follows that, by means of a course of Geometry embracing these, the subject might be introduced much sooner than it usually is.

As the beginner is always more interested in Problems than Theorems, one half of this work will be found to consist of Problems. The solutions to these are not only simple, but also practical. This is important, as the constructions generally given in theoretical works on Geometry are not employed in practice, whilst those in use are selected from treatises on Practical Geometry, and have no proofs attached to them. The Problems are mainly those of the first four Books of Euclid. The demonstrations of these, as also of the Theorems, assume no more than Euclid does in the corresponding Propositions, and may accordingly be substituted for them in examinations. This is therefore not merely a course preparatory to a more extended study of Geometry, but, in the event of its being followed by Euclid as a text-book, a great deal of the ground of his first four Books will then have been already covered by it, and in such a manner as to render the completion a matter of no great labour.

CITY OF LONDON SCHOOL,
October 1875.

PRELIMINARY NOTICES.

THE following axioms will be assumed :—

Things which are equal to the same thing are equal to one another.

The whole is equal to the sum of its parts.

If equals be added to equals the wholes are equal.

If equals be taken from equals the remainders are equal.

Things which are double of equal things are equal to one another.

Things which are halves of equal things are equal to one another.

After the first few Propositions the following symbols will be introduced :—

∠	*angle.*
Δ	*triangle.*
▱	*parallelogram.*
=	*equal to.*
∴	*therefore.*

PRIMER OF GEOMETRY.

BOOK I.

INTRODUCTION.

DEFINITIONS &c.

A straight line is one which lies evenly between its extremities.

EUCLID'S AXIOM. *Two straight lines cannot enclose a space.*

If two straight lines be drawn from a point, they will form an **angle**. Those two lines are called the **arms**, and that point is called the **vertex** of the angle.

The size of an angle does not depend on the length of its arms, but only on their direction.

If one angle can be placed on another so that the vertex of one may coincide with the vertex of the other, and the arms of one lie along the arms of the other, the angles are said to be equal to one another.

DEFINITIONS &c.

A triangle is a plane figure bounded by three straight lines, called the **sides** of the triangle.

The three angles formed by the sides are called the angles of the triangle.

If one triangle can be placed on another so that the boundary of one may coincide with the boundary of the other, then the triangles are equal to one another, the sides of the one are equal to the sides of the other, and the angles of the one to the angles of the other. The triangles are then said to be equal in all respects.

A circle is a plane figure bounded by one line, called the **circumference**, and is such that all straight lines drawn from a certain point within the figure to the circumference are equal.

That point is called the **centre**, and those straight lines are called **radii.**

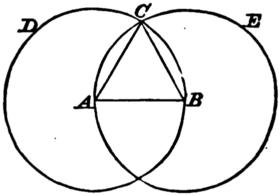
STRAIGHT LINES, ANGLES, AND TRIANGLES.

DEFINITION.

An equilateral triangle is one which has all its sides equal.

PROPOSITION I.

To describe an equilateral triangle upon a given straight line.



Let AB be the given straight line.

It is required to describe an equilateral triangle upon AB.

With centre A, and radius AB, describe the circle BCD; and with centre B, and radius BA, describe the circle ACE.

From the point C, in which these circles cut one another, draw the straight lines CA, CB.

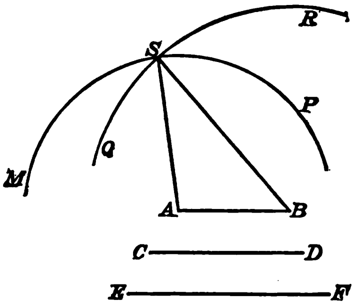
Then ABC shall be an equilateral triangle,

Because A is the centre of the circle BCD,
therefore AC is equal to AB;
and because B is the centre of the circle ACE,
therefore BC is equal to AB.
Thus AC and BC are each of them equal to AB.
Therefore AC and BC are equal to one another.
Therefore AC, BC, and AB are equal to one another.
Therefore the triangle ABC is equilateral.

Wherefore an equilateral triangle has been described upon AB. WHICH WAS TO BE DONE.

PROPOSITION II.

To describe a triangle having its sides equal to three given straight lines.



Let *AB*, *CD*, and *EF* be the three given straight lines.

It is required to describe a triangle having its sides equal to *AB*, *CD*, and *EF* respectively.

With centre *A*, and radius equal to *CD*, describe the circle *MP;*

and with centre *B*, and radius equal to *EF*, describe the circle *QR*.

If these circles intersect in *S*, join *AS* and *BS*.

Then shall *ABS* be the triangle required.

For *AS* is a radius of the circle *MP*, and is therefore equal to *CD ;*

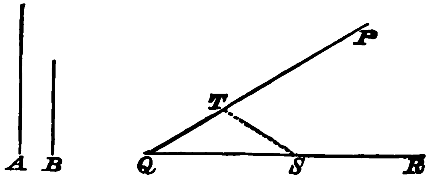
also *BS* is a radius of the circle *QR*, and is therefore equal to *EF*.

Wherefore a triangle *ABS* has been described having its sides *AB*, *AS*, *BS* respectively equal to the given straight lines *AB*, *CD*, *EF*. QUOD ERAT FACIENDUM.

Note.—If the circles do not intersect, the problem cannot be done.

Proposition III.

To describe a triangle having two of its sides equal to two given straight lines, and the angle contained by those sides equal to a given angle.



Let *A* and *B* be the given straight lines,
and *PQR* the given angle.

It is required to describe a triangle having two of its sides equal to *A* and *B*, and the angle contained by those sides equal to the angle *PQR*.

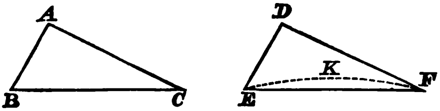
From *QR* cut off *QS*, equal to *A*;
and from *QP* cut off *QT*, equal to *B*.
Join *ST*.
Then shall the triangle *QST* be the one required.

For the triangle *QST* has two of its sides, *QS*, *QT*, equal to the two given straight lines *A* and *B*, and they contain the angle *TQS*, which is the same as the given angle *PQR*.

Wherefore a triangle has been described having two of its sides &c. Q.E.F.

PROPOSITION IV.

If two sides and the included angle of one triangle be respectively equal to two sides and the included angle of another triangle, the triangles shall be equal in all respects.



In the triangles *ABC*, *DEF*,

let the two sides *AB*, *AC*, and the included angle *BAC*, be respectively equal to the two sides *DE*, *DF*, and the included angle *EDF*.

Then shall the triangles *ABC*, *DEF* be equal in all respects.

For if the triangle *ABC* were applied to the triangle *DEF* so that the point *A* fell on the point *D*, and the straight line *AB* along *DE*, then would *AC* fall along *DF*, because the angle *BAC* is equal to the angle *EDF;*

also *B* would fall on *E*, because *AB* is equal to *DE ;* and *C* on *F*, because *AC* is equal to *DF*.

Therefore the straight line *BC* would coincide with *EF;* for if it fell otherwise, as *EKF*, then two straight lines would enclose a space, which is impossible.

Therefore *BC* would coincide with *EF*, and is therefore equal to it; and the triangle *ABC* would coincide with the triangle *DEF*, and is equal to it.

So the angle *ABC* would coincide with the angle *DEF*, and is equal to it; and the angle *ACB* would coincide with the angle *DFE*, and is equal to it.

Thus the triangle *ABC* is equal to the triangle *DEF* in all respects.

Wherefore if two sides &c.

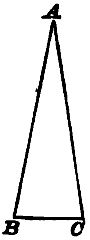
WHICH WAS TO BE PROVED.

DEFINITION.

An isosceles triangle is one which has two of its sides equal.

PROPOSITION V.

The angles at the base of an isosceles triangle are equal to one another.



Let *ABC* be an isosceles triangle, having the side *AB* equal to the side *AC*.

Then shall the angle *ABC* be equal to the angle *ACB*.

For if the triangle were taken up, reversed, and then placed so that *A* fell on its former position,

and *AB* along the former position of *AC;*

then would *AC* fall along that of *AB;*

also *B* would fall on that of *C*, because *AB* is equal to *AC*, and *C* on that of *B* for the same reason.

Therefore *BC* would fall on its former position.

Thus *AB*, *BC* would fall on the former positions of *AC*, *CB;*

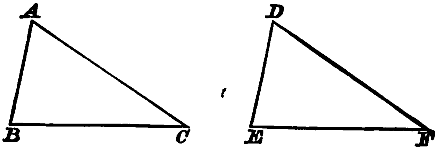
Therefore the angle *ABC* is equal to the angle *ACB*.

Wherefore the angles at the base &c.

QUOD ERAT DEMONSTRANDUM.

PROPOSITION VI.

If two angles and the adjacent side of one triangle be respectively equal to two angles and the adjacent side of another triangle, then the triangles shall be equal in all respects.



In the triangles *ABC*, *DEF*, let the two angles *ABC*, *ACB*, and the adjacent side *BC*, be respectively equal to the two angles *DEF*, *DFE*, and the adjacent side *EF*.

Then shall the triangles *ABC DEF* be equal in all respects.

For if the triangle *ABC* were applied to the triangle *DEF*, so that *BC* fell upon *EF*,

then *BA* would fall along *ED*, since the angle *ABC* is equal to the angle *DEF;*

and *CA* would fall along *FD*, since the angle *ACB* is equal to the angle *DFE.*

Therefore the point *A* would fall on the point *D*, and the triangle *ABC* would coincide with the triangle *DEF*.

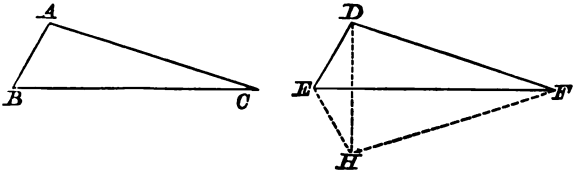
Therefore the triangles *ABC*, *DEF* are equal in all respects.

Wherefore if two angles and the adjacent side &c.

Q.E.D.

Proposition VII.

If the three sides of one triangle be respectively equal to the three sides of another, the triangles shall be equal in all respects.



Let the sides *AB*, *BC*, *CA* of the Δ *ABC* be respectively equal to the sides *DE*, *EF*, *FD* of the Δ *DEF*.

Then shall the triangles *ABC*, *DEF* be equal in all respects.

For if the Δ *ABC* were taken up, reversed, and placed so that *BC* fell on *EF*,

and *A* on the opposite side of *EF* to that on which *D* is, as at *H*,

and *HD* joined;

then would ∠ *EHD* be equal to ∠ *EDH*,

because *EH* is equal to *ED*; (I. 5)

and ∠ *FHD* be equal to ∠ *FDH*,

because *FH* is equal to *FD*; (I. 5)

and therefore ∠ *EHF* equal to ∠ *EDF*,

that is, ∠ *BAC* is equal to ∠ *EDF*,

also the sides *AB*, *AC* are respectively equal to the sides *DE*, *DF*.

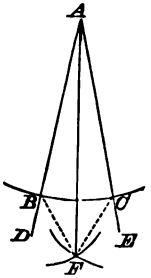
Therefore the Δ *ABC* is equal to the Δ *DEF* in all respects. (I. 4)

Wherefore if three sides of one triangle &c. Q.E.D.

Note.—For convenience, the side *BC* of Δ *ABC*, which is not less than either of the others, has been applied to the equal side of Δ *DEF*.

PROPOSITION VIII.

To bisect a given angle.



Let DAE be the given angle.
It is required to bisect it.

With centre A describe a circle cutting AD, A
B and C.

With centres B and C describe circles having e
radii, intersecting in F.

Join AF.

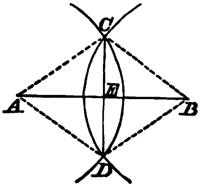
Then $\angle DAE$ shall be bisected by AF.

Join BF and CF.

Because in the $\triangle$s ABF, ACF,
the side AF is common to both;
also BA is equal to CA, because they are radii of
same circle,
and BF is equal to CF, because they are radi
equal circles;
therefore the $\triangle$ s ABF, ACF are equal in all
spects, (
and thus $\angle BAF$ is equal to the $\angle CAF$.
Wherefore $\angle DAE$ has been bisected. Q

PROPOSITION IX.

To bisect a given straight line.



Let *AB* be the given straight line.
It is required to bisect *AB*.

With centres *A* and *B* describe two circles having equal radii intersecting in *C* and *D*.

Join *CD* cutting *AB* in *E*.

Then *AB* shall be bisected in *E*.

Join *AC, CB, BD, DA*.

Now because in the Δ s *ACD, BCD* the sides *AC, CD, DA* are respectively equal to *BC, CD, DB*,

therefore the Δs *ACD, BCD* are equal in all respects,

and thus the ∠ *ACD* is equal to the ∠ *BCD*. (I. 7)

Hence in the Δs *ACE, BCE*, the two sides *AC, CE* and the included angle *ACE* are respectively equal to the two sides *BC, CE* and the included angle *BCE*.

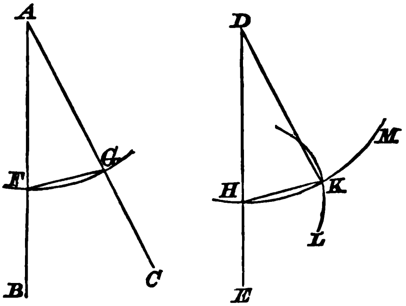
Therefore the Δs *ACE, BCE* are equal in all respects, and therefore *AE* is equal to *BE*. (I. 4)

Wherefore the given straight line *AB* has been bisected.

Q.E.F.

PROPOSITION X.

At a point in a given straight line to make an angle equal to a given angle.



Let *BAC* be the given angle.

It is required to make at the point *D* in the straight line *DE* an angle equal the given angle *BAC.*

With centre *A* describe a circle cutting *AB* and *AC* in *F* and *G;* and with centre *D* describe a circle *HKM* with equal radius cutting *DE* in *H.*

Join *FG;* and with centre *H* and radius equal to *FG* describe a circle cutting the circle *HKM* in *K.*

Join *DK.*

Then *EDK* shall be the angle required.

Join *HK.*

Then because in the Δs *HDK*, *FAG* the sides *HD*, *DK*, and *KH* are respectively equal to *FA*, *AG*, and *GF;*

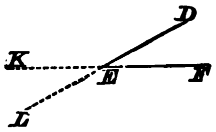
therefore $\angle$ *HDK* is equal to $\angle$ *FAG.* (I. 7)

Wherefore at the point *D* in the straight line *DE* an angle *EDK* has been made equal to the given angle *BAC.* Q.E.F.

VERTICAL ANGLES.

PROPOSITION XI.

If two straight lines cut one another, the vertical (or opposite) angles shall be equal to one another.



Let the two straight lines *DEL*, *FEK* cut one another.

Then shall ∠ *DEF* be equal to the vertical ∠ *KEL*.

For if the figure were taken up, reversed, and placed so that each of the arms of ∠ *DEK* might fall along the former position of the other arm; that is, so that

ED might fall along the former position of *EK*, and *EK* along that of *ED*;

then would *EK* produced, or *EF*, fall along that of *ED* produced, or *EL*.

Thus *EF* and *ED* would fall along the former positions of *EL* and *EK*.

Therefore ∠ *DEF* is equal to ∠ *KEL*.

Wherefore if two straight lines &c. Q.E.D.

RIGHT ANGLES.

DEFINITION.

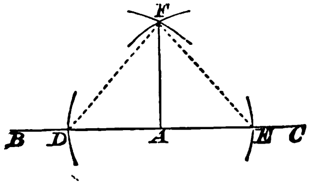
When one straight line, standing on another straight line, makes the adjacent angles equal to one another, each of them is called **a right angle;**

and the straight line which stands upon the other is said to be **perpendicular** to it.

EUCLID'S AXIOM.—*All right angles are equal to one another.*

PROPOSITION XII.

To draw a perpendicular to a given straight line from a given point in the same.



Let BC be the given straight line,
and A the given point in it.
It is required to draw from A a perpendicular to BC.

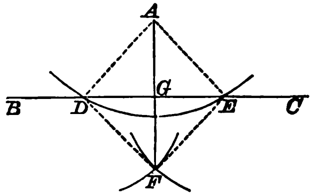
From AB, AC cut off equal parts AD, AE.
With D and E as centres, describe circles with equal radii intersecting in F.
Join AF.
Then shall AF be perpendicular to BC.

Join DF and EF.

Because the side AF is common to the $\triangle$s DAF, EAF, and AD is equal to AE, and also DF is equal to EF;
therefore $\triangle$s DAF, EAF are equal in all respects, (I. 7)
and thus $\angle DAF$ is equal to $\angle EAF$.
Therefore AF is perpendicular to BC. (Def.)
Wherefore from a given point &c. Q.E.F.

PROPOSITION XIII.

To draw a perpendicular to a given straight line from a given point without it.



Let *A* be the given point without the given straight line *BC*.

It is required to draw from *A* a perpendicular to *BC*.

With centre *A* describe a circle cutting *BC* at *D* and *E*.

With centres *D* and *E* describe circles with equal radii intersecting in *F*.

Join *AF*, cutting *BC* in *G*.

Then shall *AG* be perpendicular to *BC*.

Join *AD*, *AE*, *FD*, and *FE*.

Now because in the △s *DAF*, *EAF* the sides *DA*, *AF*, and *FD* are respectively equal to *EA*, *AF*, and *FE*;

∴ ∠ *DAF* is equal to ∠ *EAF*. (I. 7)

Again, because in the △s *DAG*, *EAG* the sides *DA*, *AG* and the included angle *DAG* are respectively equal to *EA*, *AG* and the included angle *EAG*;

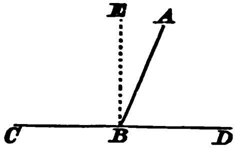
∴ ∠ *DGA* is equal to ∠ *EGA*; (I. 4)

∴ *AG* is perpendicular to *BC*. (Def.)

Wherefore from a given point &c. Q.E.F.

PROPOSITION XIV.

The angles which one straight line makes with another upon one side of it are either two right angles or are together equal to two right angles.



Let the straight line *AB* make with *CD* upon one side of it the ∠s *ABC, ABD.*

These shall either be two right angles or shall together be equal to two right angles.

If the ∠ *ABC* is equal to the ∠ *ABD;*
then each of them is a right angle. (Def.)

But if not, through *B* draw *BE* perpendicular to *CD;* (I. 12)

then the ∠ *ABC* is equal to the ∠s *CBE* and *EBA* together;

therefore the ∠s *ABC* and *ABD* are together equal to the ∠s *CBE*, *EBA*, and *ABD*,
of which ∠ *CBE* is a right angle,
and ∠s *EBA* and *ABD* together make up a right angle.

Therefore the ∠s *ABC* and *ABD* are together equal to two right angles.

Wherefore the angles which one straight line &c.

Q.E.D.

COROLLARY.—*If two angles be equal to one another, then the adjacent angles, formed by producing an arm of each through the vertex, will be equal to one another.*

PARALLELS.

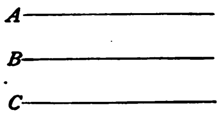
Definition.

Straight lines, lying in the same plane and which will never meet, though produced ever so far both ways, are called **parallel.**

Playfair's Axiom.—*Two straight lines which cut one another cannot be parallel to the same straight line.*

Proposition XV.

Straight lines which are parallel to the same straight line are parallel to one another.



Let the straight lines *A* and *B* be each of them parallel to *C*.

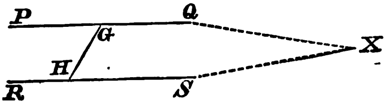
Then shall *A* and *B* be parallel to one another.

For if not, they will meet if produced, and there will thus be two intersecting straight lines parallel to the same straight line, which is impossible. (Axiom.)

Wherefore straight lines &c. Q.E.D.

PROPOSITION XVI.

If, in a plane, a straight line, meeting two other straight lines, make the alternate angles equal to one another, these two straight lines shall be parallel.



Let the straight line *GH*, meeting the two straight lines *PQ*, *RS*, make the alternate $\angle$s *HGP*, *GHS* equal to one another, and therefore also the alternate $\angle$s *HGQ*, *GHR* equal to one another. (I. 14, Cor.)

Then shall *PQ*, *RS* be parallel.

For if not, *PQ*, *RS* when produced will meet either towards *Q* and *S* or towards *R* and *P*.

Let them, if possible, meet when produced towards *Q* and *S* in the point *X*.

Thus *GHX* is a Δ, and if it were applied to *GH* on the opposite side, then *HX* would fall along *GP*, because $\angle$ *HGP* is equal to $\angle$ *GHS;* and *GX* would fall along *HR*, because $\angle$ *GHR* is equal to $\angle$ *HGQ*.

Therefore *GP*, *HR* would meet if produced towards *P* and *R*, and thus two straight lines would enclose a space, which is impossible.

Therefore *PQ*, *RS* will not meet if produced towards *Q* and *S*.

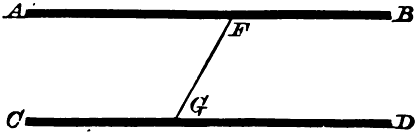
Similarly it may be shown that they will not meet if produced towards *P* and *R*.

Therefore *PQ* and *RS* are parallel.

Wherefore if in a plane a straight line &c. Q.E.D.

PROPOSITION XVII.

To draw a straight line through a given point parallel to a given straight line.



Let *F* be the given point, and *CD* the given straight line.

It is required to draw a straight line through *F* parallel to *CD*.

Join *F* with any point *G* in *CD*.

At the point *F* in *FG* make ∠ *GFA* equal to ∠ *FGD*, and produce *AF* to *B*. (I. 10)

Then shall *AB* be parallel to *CD*.

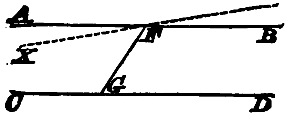
For since *FG*, meeting the two straight lines *AB* and *CD*, makes the alternate angles *GFA*, *FGD* equal to one another,

therefore *AB* is parallel to *CD*. (I. 16)

Wherefore a straight line has been drawn &c. Q.E.F.

PROPOSITION XVIII.

If a straight line meet two parallel straight lines, the alternate angles shall be equal to one another.



Let the straight line *FG* meet the two parallel straight lines *AB* and *CD*.

Then shall ∠ *GFA* be equal to the alternate ∠ *FGD*.

For, if possible, let them be unequal, and at *F* in *FG* make ∠ *GFX* equal to ∠ *FGD*. (I. 10)

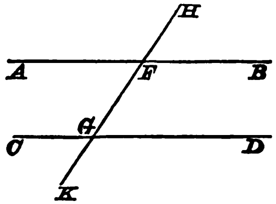
Then *XF* is parallel to *CD*. (I. 16)

Therefore through *F* two straight lines have been drawn parallel to *CD*, which is impossible.

Therefore ∠ *GFA* is not unequal to ∠ *FGD*—that is, it is equal to it.

Wherefore if a straight line &c. Q.E.D.

COROLLARY 1.—*If a straight line fall upon two parallel straight lines, the exterior angle shall be equal to the interior and opposite angle upon the same side of the line.*



Let HK fall upon the two parallel straight lines AB, CD;

then shall $\angle HFB$ be = $\angle FGD$.

For $\angle AFG$ is = the alternate $\angle FGD$;

and $\angle AFG$ is = the vertical opposite $\angle HFB$; (I. 11)

therefore $\angle HFB$ is = $\angle FGD$.

COROLLARY 2.—*If a straight line fall upon two parallel straight lines, the two interior angles upon the same side of the line shall together be equal to two right angles.*

That is, the $\angle$s BFG, FGD shall be together equal to two right angles.

For $\angle AFG$ is = the alternate $\angle FGD$;

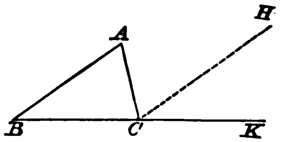
therefore the $\angle$s BFG, AFG are together = the $\angle$s BFG, FGD;

but the $\angle$s BFG, AFG are together = two right angles; (I. 14)

therefore $\angle$s BFG, FGD are together = two right angles.

PROPOSITION XIX.

If one side of a triangle be produced, the exterior angle shall be equal to the two interior and opposite angles.



Let *ABC* be a △,
and let one of its sides *BC* be produced to *K*.

Then shall the exterior angle *ACK* be equal to the two interior and opposite angles *BAC*, *ABC*.

Through *C* draw *CH* parallel to *AB*. (I. 17)

Now because *CH* is parallel to *AB*, and *AC* meets them,

∴ the ∠ *ACH* is = the alternate ∠ *BAC*. (I. 18)

Again, because *CH* is parallel to *AB*, and *BK* falls upon them;

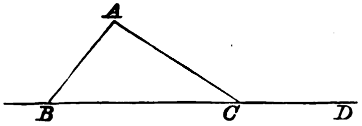
∴ the exterior ∠ *HCK* is = the interior and opposite ∠ *ABC*; (I. 18, Cor.)

∴ the whole ∠ *ACK* is = the two angles *BAC*, *ABC* together.

Wherefore if one side of a triangle &c. Q.E.D.

PROPOSITION XX.

The three angles of a triangle are together equal to two right angles.



Let *ABC* be a Δ.

Then shall its three angles be together equal to two right angles.

Produce *BC* to *D*.

Then the exterior angle *ACD* is = the two ∠s *ABC*, *BAC* together. (I. 19)

Add to each of these equals the ∠ *ACB*;

∴ the ∠s *ACD*, *ACB* are together = the ∠s *ABC*, *BAC*, *ACB*,

i.e. = the three ∠s of Δ *ABC*.

But the ∠s *ACD*, *ACB* are together = two right angles; (I. 14)

∴ the three ∠s of Δ *ABC* are together = two right ∠s. **Q.E.D.**

PARALLELOGRAMS.

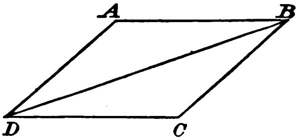
DEFINITIONS.

A parallelogram is a four-sided figure, of which the opposite sides are parallel.

A straight line joining two opposite angles of a parallelogram is called **a diagonal.**

PROPOSITION XXI.

The opposite sides and angles of a parallelogram are equal, and the diagonal bisects it.



Let $ABCD$ be a ▱, and BD a diagonal.
Then shall AB be $= DC$, $AD = BC$,
$\angle BAD = \angle BCD$, $\angle ABC = \angle ADC$,
and $\triangle ABD = \triangle CDB$.

Because AB is parallel to DC.

$\therefore$ the alternate $\angle$s ABD, BDC are equal to one another, (I. 18)

and because AD is parallel to BC,

$\therefore$ the alternate $\angle$s ADB, DBC are equal to one another; (I. 18)

$\therefore$ the whole $\angle ABC$ is $=$ the whole $\angle ADC$.

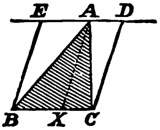
Also, because in the $\triangle$s ABD, CDB the $\angle$s ABD, ADB are respectively equal to the $\angle$s CDB, CBD, and the side DB adjacent to the equal $\angle$s in each is common;

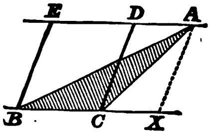
$\therefore$ the $\triangle$s ABD, CDB are equal in all respects, and AB, AD, and $\angle BAD$ are respectively equal to DC, BC, and $\angle BCD$. (I. 6)

Wherefore the opposite sides &c. Q.E.D.

Proposition XXII.

If a parallelogram and a triangle be on the same base and between the same parallels, the parallelogram shall be double of the triangle.





Let the ▱ *EBCD* and the Δ *ABC* be on the same base *BC*, and between the same parallels.

Then shall ▱ *EBCD* be double of the Δ *ABC*.

If the vertex *A* of the Δ *ABC* be at *D* or *E* the proposition is evident. (I. 21)

But if not, through *A* draw *AX* parallel to *EB* or *DC*, meeting the base or base produced in *X*.

Then *EX* is a ▱ and is ∴ double of Δ *ABX;* (I. 21)
also *DX* is a ▱ and is ∴ double of Δ *ACX;* (I. 21)
∴ ▱ *EC* is double of Δ *ABC*.

Wherefore if a parallelogram &c. Q.E.D.

Corollary 1.—*If there be any number of* ▱*s on the same base and between the same parallels, they will be equal to one another.*

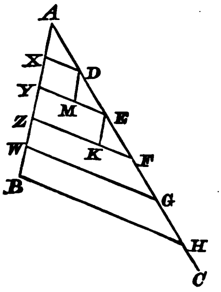
For each of them will be double of any Δ which may be drawn on that base and between those parallels.

Corollary 2.—*If there be any number of* Δ*s on the same base and between the same parallels, they will be equal to one another.*

For each of them will be half of any ▱ which may be drawn on that base and between those parallels.

PROPOSITION XXIII.

To divide a straight line into any given number of equal parts.



Let it be required to divide the straight line *AB* into five equal parts.

From *A* draw another straight line *AD*, and from *AD* produced cut off *DE*, *EF*, *FG*, *GH*, each equal to *AD*.

Join *HB*, and draw *DX*, *EY*, *FZ*, *GW* parallel to it; (I. 17)

ana cutting *AB* in *X*, *Y*, *Z*, *W*.

Then shall *AB* be divided into five equal parts.

Draw *DM*, *EK* parallel to *AB*.

Then because *DM* is parallel to *AB*, and *AE* falls upon them,

$\therefore \angle MDE = \angle XAD$, (I. 18, Cor. 1) and because EM is parallel to DX, and AE falls upon them,

$\therefore \angle DEM = \angle ADX$. (I. 18, Cor. 1)

Also DE is $= AD$,

$\therefore$ the $\triangle$s DEM, ADX are equal in all respects, (I. 6)

and thus DM is equal to AX.

But $DM = XY$, (I. 21)

$\therefore XY = AX$.

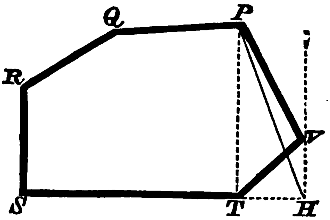
Similarly YZ, ZW, and WB may be proved to be equal to AX.

Hence AB is divided into five equal parts.

In like manner may a straight line be divided into any given number of equal parts. Q.E.F.

PROPOSITION XXIV.

To describe a triangle equal to a given rectilineal figure.



Let *PQRSTV* be the given rectilineal figure.

It is required to describe a triangle equal to it.

Join *PT.*

Draw through *V* the straight line *VH* parallel to *PT,* meeting *ST* produced in *H.* (I. 17)

Join *PH.*

Then since the Δs *PTH, PTV* are upon the same base *PT,*

and between the same parallels *VH*, *PT* ;

$\therefore \triangle PTH = \triangle PTV.$ (I. 22, Cor. 2)

Add to each of these equals the figure $PQRST$;

$\therefore$ the figure $PQRSH$ is $=$ figure $PQRSTV$.

Similarly a figure may be described $= PQRSH$ having one fewer sides; and so on.

Thus a triangle may be described &c. Q.E.F.

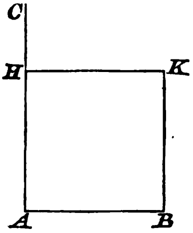
SQUARES.

DEFINITION.

A square is a four-sided figure, having all its sides equal to one another, and all its angles right angles.

PROPOSITION XXV

To describe a square on a given straight line.



Let *AB* be the given straight line.

It is required to describe a square on *AB*.

Through *A* draw *AC* perpendicular to *AB*, (I. 12)
and from *AC* cut off *AH* = *AB*.

Through H draw *HK* parallel to *AB*, (I. 17)

and through B draw BK parallel to AH, (I. 17)
and meeting HK in K.

Then shall $ABKH$ be the square required.

For, by construction, $ABKH$ is a parallelogram.

$\therefore$ $AB = HK$, and AH is $= BK$; (I. 21)

also AH was made $= AB$;

$\therefore$ $ABKH$ has all its sides equal.

Again, since HK is parallel to AB,

$\therefore$ $\angle$s BAH, AHK are together = two right angles; (I. 18, Cor. 2)

but $\angle BAH$ is a right angle, $\therefore$ $\angle AHK$ is a right angle.

$\therefore$ the $\angle$s BKH, ABK opposite to these are right angles; (I. 21)

$\therefore$ all the angles of $ABKH$ are right angles.

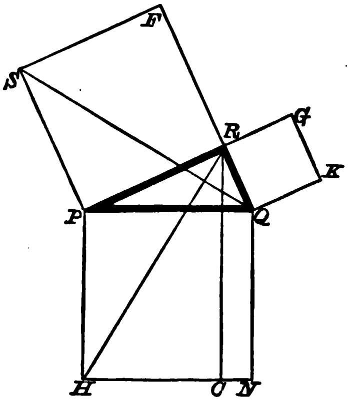
Therefore $ABKH$ is a square.
Wherefore a square has been described on AB.

Q.E.F.

COROLLARY.—*If one angle of a parallelogram is a right angle, all its angles are right angles.*

PROPOSITION XXVI.

In any right-angled triangle, the square described on the side opposite the right angle is equal to the squares described on the sides containing the right angle.



Let *PQR* be a right-angled triangle.

Then shall the square on *PQ*, the side opposite the right angle, be equal to the squares on *PR* and *RQ*.

Produce *PR* and *QR*, then the ∠s at *R* are right angles.

Complete the squares on *PR* and *QR*, and describe *the square on PQ*. (I. 25)

Through R draw RC parallel to PH. Join RH and SQ.

Then the right $\angle\ SPR$ is = the right $\angle\ QPH$;

add to each the $\angle\ RPQ$;

$\therefore$ the $\angle\ SPQ$ is = the $\angle\ RPH$.

Also the sides SP, PQ are respectively = the sides RP, PH;

$\therefore$ the $\Delta\ SPQ$ is = the $\Delta\ RPH$. (I. 4)

But the ▱ PC is double of the $\Delta\ RPH$, because they are on the same base PH, and between the same parallels; (I. 22)

and so likewise $SPRF$ is double of the $\Delta\ SPQ$; (I. 22)

$\therefore$ the ▱ PC is = $SPRF$ which is the square on PR.

Similarly it may be proved that the ▱ QC is = the square on RQ.

$\therefore$ the whole figure $PHNQ$, which is the square no PQ, is = the squares on PR and RQ.

Wherefore in any right-angled triangle &c. Q.E.D.

BOOK II.

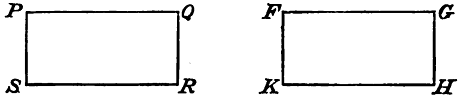
RECTANGLES.

DEFINITION.

A **rectangle** is a right-angled parallelogram.

PROPOSITION I.

If two adjacent sides of one rectangle be respectively equal to two adjacent sides of another, the rectangles shall be equal to one another.



Let the two adjacent sides *PQ*, *QR* of the rectangle *PR* be respectively equal to the two adjacent sides *FG*, *GH* of the rectangle *FH*.

Then shall the rectangle *PR* be equal to the rectangle *FH*.

For let *PR* be applied to *FH*, so that *PQ* may fall on *FG*, then will QR fall along GH, since $\angle\ PQR = \angle\ FGH$,

and R will fall on H, since $QR = GH$;

so likewise will RS and SP fall on HK and KF.

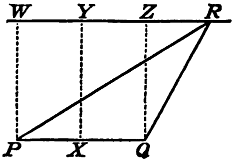
Thus the figure $PQRS$ will coincide with the figure $FGHK$, and is therefore equal to it.

Wherefore if two adjacent sides &c. Q.E.D.

Note.—A rectangle is said to be contained by any two of its adjacent sides: thus the rectangle $PQRS$ will be spoken of as the "rectangle contained by PQ, QR," which for brevity may be written thus—"the rectangle PQ, QR."

PROPOSITION II.

To describe a rectangle equal to a given triangle.



Let PQR be the given triangle.

It is required to describe a rectangle equal to the Δ PQR.

Through R draw a straight line RW parallel to PQ. (I. 17)

Bisect PQ in X. (I. 9)
Draw XY perpendicular to PQ, (I. 12)
and QZ parallel to XY. (I. 17)
Then $XQZY$ is a rectangle;
also it shall be the one required.

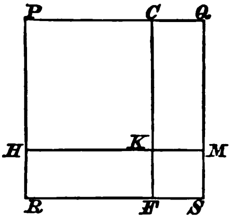
Draw PW parallel to XY. (I. 17)

Then rectangle PY = rectangle QY, (II. 1)
$\therefore$ QY is half of QW.
But Δ PQR is half of QW, (I. 22)
$\therefore$ rectangle $QY = \Delta\ PQR$.

Wherefore a rectangle has been described equal to the given triangle. Q.E.F.

PROPOSITION III.

If a straight line be divided into any two parts, the square on the whole line will be equal to the squares on the two parts, together with twice the rectangle contained by the parts.



Let the straight line PQ be divided into any two parts in C.

Then shall the square on PQ be equal to the squares on PC, CQ, together with twice the rectangle contained by PC, CQ.

Draw PR perpendicular to PQ, and equal to it. (I. 12)
Cut off $PH = PC$, so that HR is $= CQ$.
Draw HM and RS parallel to PQ; (I. 17)
also CF and QS parallel to PR. (I. 17)

Then $PRSQ$ is a square, (I. 25)
and it is equal to the figures PK, KS, CM, HF together.

Now PK is the square on PC; (I. 25)

KS is the square on KM, and is therefore = the square on CQ, for KM is $= CQ$; (I. 21)

CM is the rectangle contained by CK, CQ, and is therefore = the rectangle PC, CQ, for CK is $= PC$;

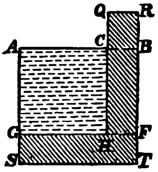
and HF is also = rectangle PC, CQ, for HK is $= PC$, and $HR = CQ$.

Therefore the square on PQ is = the squares on PC, CQ, together with twice the rectangle PC, CQ.

Wherefore if a straight line &c. Q.E.D.

PROPOSITION IV.

If a straight line be divided into any two parts, the square on one part will be less than the squares on the whole and on the other part by twice the rectangle contained by the whole and that other part.



Let the straight line *AB* be divided into any two parts in *C*.

Then shall the square on *AC* be less than the squares on *AB* and *BC* by twice the rectangle *AB*, *BC*.

Draw *AGS* perpendicular to *AB*; (I. 12)

also *QCH* and *RBT* parallel to *AGS*. (I. 17)

Cut off *AG* = *AC*, *AS* = *AB*, and *BR* = *BC*.

Draw *GHF*, *ST*, and *RQ* parallel to *AB*. (I. 17)

Then *AH*, *AT*, and *BQ* are squares, (I. 25)

and we have to show that

AH is less than *AT* and *BQ* by twice the rectangle *AB, BC*;

that is, that the figure *GTQ* is = twice the rectangle *AB, BC*.

Now the figure *GT* is = the rectangle *AB, BC*,
for *GF* is = *AB*, and *GS* = *BC*;
also the figure *QF* is = the rectangle *AB, BC*,
for *RF* is = *AB*, and *QR* = *BC*.

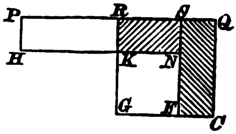
Therefore the figure *GTQ* is = twice the rectangle *AB, BC*.

Therefore the square on *AC* is less than the squares on *AB*, *BC* by twice the rectangle *AB*, *BC*.

Wherefore if a straight line &c. Q.E.D.

PROPOSITION V.

The difference between the squares on any two straight lines is equal to the rectangle contained by two straight lines, one of which is equal to the sum, and the other equal to the difference of the given lines.



Let RQ, RS be equal to the given straight lines.
Then SQ is = the difference between them.
Produce QR to P, making $RP = QR$.
Then PS is = the sum of the given lines.
The difference between the squares on RQ and RS shall be equal to the rectangle PS, SQ.

On RQ describe a square $RGCQ$. (I. 25)
Draw PH perpendicular to PQ, and equal to SQ; (I. 12)
also SF parallel to RG, and HKN parallel to PQ. (I. 17)

Then KF is = the square on RS, for KN is = RS.

∴ the difference between the squares on RQ, RS is = the figure KQF.

Hence we have to show that the figure KQF is = the rectangle PS, SQ.

Now the rectangle QF is = the rectangle PK, for $QS = PH$, and $QC = PR$.

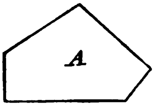
∴ the figure KQF is = the figure PN, which is = the rectangle PS, SQ, for PH is = SQ.

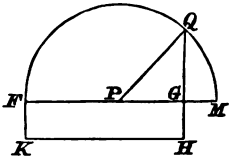
∴ the difference between the squares on RQ, RS is = the rectangle PS, SQ.

Wherefore the difference &c. Q.E.D.

PROPOSITION VI.

To describe a square equal to a given rectilineal figure.





Let A be the given rectilineal figure.

It is required to describe a square equal to A.

First describe the rectangle $FGHK = A$. (I. 24; II. 2)

Produce FG, and cut off $GM = GH$.

Bisect FM in P, and with centre P and radius PM describe circle FQM.

Produce HG to meet the circumference in Q.

The square on GQ shall be $= A$.

Join PQ.

Then since FG is = the sum and GM = the difference of PM and PG;

$\therefore$ the rectangle FG, GM is = the difference of the squares on PM and PG, (II. 5)

and $\therefore$ = the difference of the squares on PQ and PG,

and $\therefore$ = the square on GQ; (I. 26)

but FH is = the rectangle FG, GM, for $GH = GM$.

Therefore the square on GQ is $= FH$, and $\therefore = A$.

Wherefore &c. Q.E.F.

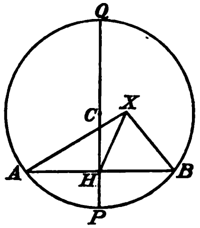
BOOK III.

CIRCLES.

THE CENTRE.

PROPOSITION I.

To find the centre of a given circle.



Let ABQ be the given circle.

It is required to find the centre of the circle ABQ

Join A, B any two points in the circumference.

Bisect AB in H.

Through *H* draw a straight line perpendicular to *AB*, meeting the circumference in *P*, *Q*. (I. 12)

Bisect *PQ* in *C*. (I. 9)

Then shall *C* be the centre of the circle *ABQ*.

For if not, if possible, let some point without *PQ*, as *X*, be the centre, and join *AX*, *HX*, *BX*.

Then because *AH*, *HX*, *XA* are respectively = *BH* *HX*, *XB*,

∴ ∠*AHX* is = ∠*BHX*; (I. 7)

∴ ∠*AHX* is a right ∠; but ∠*AHQ* is a right ∠;

∴ ∠*AHX* = ∠*AHQ*, the greater = the less, which is impossible.

∴ no point without *PQ* is the centre.

∴ the centre is in *PQ*, and is ∴ at its middle point *C*.

Wherefore the centre of the circle has been found.

Q.E.F.

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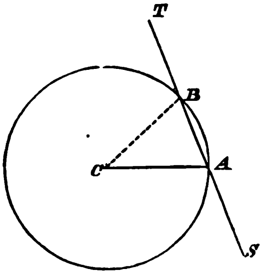
TANGENTS.

DEFINITION.

A straight line which meets a circle, and which, if produced, will not cut it, is said to **touch the circle**, and is called a **tangent** to it.

PROPOSITION III.

The straight line drawn through any point in the circumference of a circle perpendicular to the radius at that point touches the circle.



Let A be any point in the circumference of the circle AB.

Join A with the centre C, and through A draw ST perpendicular to CA.

Then ST shall touch the circle.

For, if possible, let ST cut the circle in B.

Join BC.

Then because $CB = CA$, $\therefore \angle CBA = \angle CAB$; (I. 5)

but $\angle CAB$ is a right angle; $\therefore \angle CBA$ is a right angle.

$\therefore$ two of the angles of a triangle are right angles, which is impossible; (I. 20)

$\therefore SAT$ does not cut the circle in the point B.

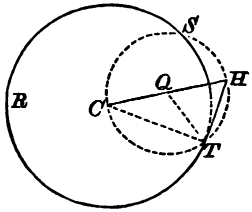
Similarly it has no other point besides A in common with the circumference;

$\therefore SAT$ touches the circle at the point A.

Wherefore the straight line &c. Q.E.D.

PROPOSITION IV.

To draw a tangent to a circle from a given point.



If the given point is on the circumference, then the straight line drawn perpendicular to the radius through that point will be a tangent. (III. 3)

If the given point is without the circle, as *H*, join it with *C* the centre of the given circle.

Bisect *CH* in *Q*; and with centre *Q* and radius *QC* or *QH* describe a circle cutting the given circle in *T*.

Join *HT*.

Then *HT* shall touch the given circle.

Join *QT*.

Because $CQ = QT$, $\therefore \angle QCT$ is $= \angle QTC$. (I. 5)

So also $\angle QHT = \angle QTH$.

$\therefore \angle$ s QCT, QHT are together = the whole $\angle CTH$;

but the $\angle$ s of the Δ CTH are together = two right angles. (I. 20)

$\therefore \angle CTH$ is a right angle.

$\therefore HT$ touches the circle RST. (III. 3)

Wherefore a tangent &c. Q.E.F.

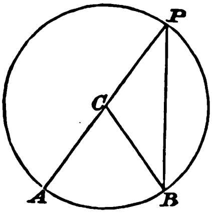
ANGLES IN CIRCLES.

DEFINITION.

An arc of a circle is a part of the circumference.

PROPOSITION V.

The angle at the centre of a circle is double of the angle at the circumference upon the same arc.



Let AB be an arc of a circle of which C is the centre,

ACB the angle upon AB at the centre,

and APB an angle upon AB at the circumference.

Then shall $\angle ACB$ be double of $\angle APB$.

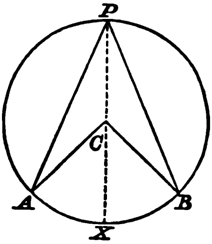
1*st.* Let the centre lie in one of the arms AP of $\angle APB$.

Then because $CP = CB$, $\therefore$ $\angle CPB = \angle CBP$; (I. 5)

but $\angle ACB = \angle$s CPB and CBP together. (I. 19)

$\therefore$ $\angle ACB$ is double of $\angle CPB$; *i.e.*, $\angle APB$.

2dly. Let *C* lie within the angle *APB*.



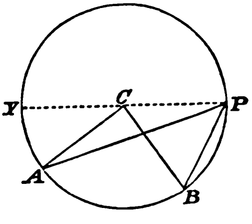
Join *PC*, and produce it to meet the circumference in *X*.

Then ∠ *ACX* is double of ∠ *APX*,

and ∠ *BCX* is double of ∠ *BPX*;

∴ the whole ∠ *ACB* is double of ∠ *APB*.

3dly. Let *C* lie without the ∠ *APB*.



Join *PC*, and produce it to meet the circumference in *Y*.

Then ∠ *BCY* is double of ∠ *BPY*,

and ∠ *ACY* is double of ∠ *APY*;

∴ the remaining ∠ *ACB* is double of ∠ *APB*.

Wherefore the angle &c. Q.E.D.

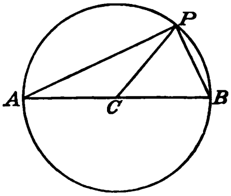
DEFINITION.

A segment of a circle is the figure contained by a part of the circumference and the straight line joining its extremities, which is called the **base** of the segment.

An angle in a segment is the angle contained by two straight lines drawn from any point in the arc of the segment to the extremities of the base.

PROPOSITION VI.

The angle in a semicircle is a right angle.



Let *APB* be an angle in the semicircle *APB*.
Then shall $\angle APB$ be a right angle.

Join *P* with *C*, the centre of the circle of which the semicircle *APB* is a segment.

Then since $AC = CP$, $\therefore \angle APC = \angle CAP$, (I. 5)
and since $BC = CP$, $\therefore \angle BPC = \angle CBP$; (I. 5)
$\therefore$ the whole $\angle APB$ = the $\angle$s *CAP*, *CBP* together;
but the three $\angle$s of $\triangle APB$ are together = two right angles; (I. 20)

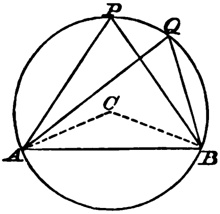
$\therefore \angle APB$ is a right angle.

Wherefore the angle in a semicircle is a right angle.

Q.E.D.

PROPOSITION VII.

The angles in the same segment of a circle are equal to one another.



Let *APB*, *AQB* be angles in the same segment *APQB*.

Then shall the ∠ s *APB*, *AQB* be equal to one another.

First, let the segment *APQB* be greater than a semicircle.

Join *A* and *B* with *C* the centre of the circle of which *APB* is a segment.

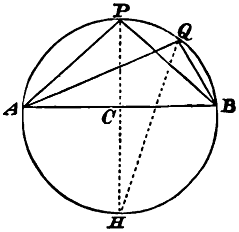
Then ∠ *ACB* is double of each of the ∠ s *APB*, *AQB*; (III. 5)

∴ ∠ s *APB*, *AQB* are equal to one another.

Next, let the segment *APQB* be not greater than a semicircle.

Draw *PCH* through the centre *C*, and join *HQ*.

Then the ∠ s *APH*, *AQH* are in a segment greater than a semicircle, and are ∴ equal to one another.



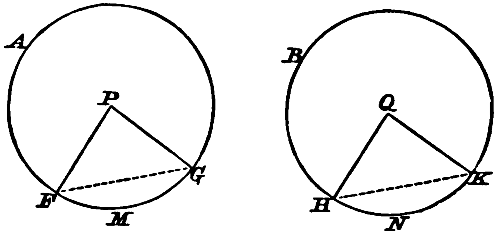
Similarly ∠ s *BPH*, *BQH* are equal to one another.

∴ the whole ∠ *APB* is = the whole ∠ *AQB*.

Wherefore the angles &c. Q.E.D.

PROPOSITION VIII.

In equal circles equal angles stand upon equal arcs.



Let *AFM*, *BHN* be equal circles, and let the ∠s *FPG*, *HQK* at their centres be equal to one another.

Then shall the arc *FMG* be equal to the arc *HNK*.

For let the circle *AFM* be applied to the circle *BHN*,
so that *P* may fall on *Q*,
and the circumference *AFM* on the circumference *BHN*;
then if *PF* fall on *QH*,
PG will fall on *QK*, since ∠ *FPG* is = ∠ *HQK*.
∴ the arc *FMG* will fall on the arc *HNK*,
and is therefore equal to it.
Wherefore in equal circles &c. Q.E.D.

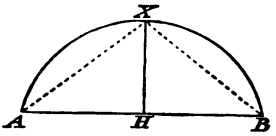
COROLLARY.—*In equal circles, or in the same circle, equal chords cut off equal arcs.*

For if the chord *FG* be = the chord *HK*;
since also *PF* and *PG* are respectively equal to *QH* and *QK*;
∴ ∠ *FPG* is = ∠ *HQK*; (I. 7)
∴ arc *FMG* is = arc *HNK*.

ON THE SUBDIVISION OF THE CIRCUMFERENCE OF A CIRCLE.

PROPOSITION IX.

To bisect a given arc of a circle.



Let AXB be the given arc of a circle.

It is required to bisect it.

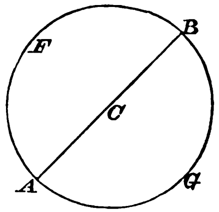
Join AB and bisect it in H. (I. 9)
Through H draw HX perpendicular to AB, (I. 12)
cutting the arc in X.
The arc AXB shall be bisected in X.

Join AX and XB.

Because $AH = HB$ and HX is common to the Δs AHX, BHX;
and also $\angle AHX$ is $= \angle BHX$;
$\therefore AX = BX$ (I. 4)
$\therefore$ arc AX is $=$ arc BX (III. 8, Cor.)
Wherefore the given arc has been bisected. Q.E.F.

PROPOSITION X.

To bisect the circumference of a circle.



Let AFB be the given circle.

It is required to bisect its circumference.

Through the centre C draw any diameter ACB,
then shall the circumference be bisected by ACB.

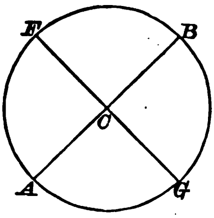
For if the circle were taken up, inverted, and then applied to its former position so that ACB should fall on its former position,

then would the arc AGB fall upon the arc AFB;

$\therefore$ arc AGB = arc AFB.

Wherefore the circumference &c. Q.E.F.

COROLLARY.—*Hence the circumference of a circle may be divided into* 4, 8, 16, 32, *&c., equal arcs.*



For if through *C*, *FCG* be drawn perpendicular to *ACB*,

then *FCG* will bisect the arcs *AGB*, *AFB*; (III. 9)

∴ the circumference will be divided into *four* equal parts.

Again, if the angles at the centre be bisected,

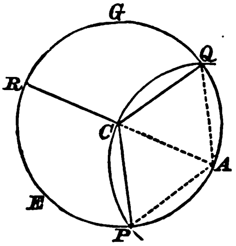
then each of the arcs *AG*, *GB*, *BF*, *FA* will be bisected, (III. 8)

and ∴ the circumference will be divided into *eight* equal parts.

And so on.

PROPOSITION XI.

To trisect the circumference of a circle.



Let *GEA* be the given circle.

It is required to trisect its circumference.

Join *C* the centre with any point *A* in the circumference.

With *A* as centre at distance *AC* describe a circle, cutting *GEA* in *P* and *Q*.

Produce *AC* to meet *GEA* in the point *R*.

Then shall the circumference of *GEA* be trisected in *P*, *Q*, *R*.

Join *CP*, *CQ*, *AP*, *AQ*.

Then Δs *ACP*, *ACQ* are equilateral, and ∴ equiangular; (I. 5)

∴ each of the ∠s *ACP*, *ACQ* is = a third of two right angles; (I. 20)

∴ each of the ∠s *PCR*, *QCR* is = two-thirds of two right angles: (I. 14)

also ∠ *PCQ* is = two-thirds of two right angles.

∴ ∠s *PCR*, *QCR*, *PCQ* are equal to one another.

∴ the arcs *PR*, *QR*, *PQ* are equal to one another. (III. 8)

Wherefore the circumference *GEA* has been trisected.

Q.E.F.

COROLLARY.—*Hence the circumference of a circle may be divided into* 6, 12, 24, *&c., equal parts.*

If *PC*, *QC* be produced to meet the given circumference *GEA*,

it will be divided into six equal arcs.

And so on.

BOOK IV.

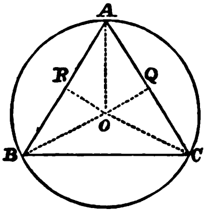
INSCRIBED AND CIRCUMSCRIBED FIGURES.

DEFINITION.

A circle is said to be *described about* a rectilineal figure when the circumference of the circle passes through all the angular points of the figure.

PROPOSITION I.

To describe a circle about a given triangle.



Let ABC be the given triangle.

It is required to describe a circle about the Δ ABC.

Bisect AC in Q and AB in R. (I. 9)

Through Q and R draw straight lines perpendicular to AC and AB intersecting in O. (I. 12)

Join OA, OB, OC.

With O as centre and OA as radius describe a circle; it shall be the one required.

Because AR, RO, and $\angle\ ARO$ are respectively equal to BR, RO, and $\angle\ BRO$,

$\therefore OA = OB$. (I. 4)

Similarly $OA = OC$;

$\therefore$ the circle passes through B and C, and $\therefore$ is described about the $\Delta\ ABC$.

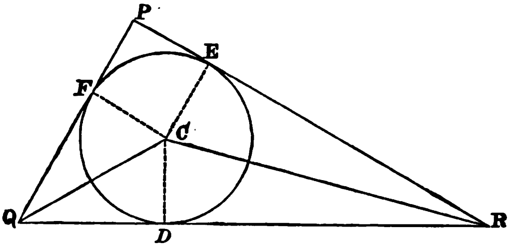
Wherefore a circle &c. Q.E.F.

DEFINITION.

A circle is said to be **inscribed in** a rectilineal figure when each side of the figure touches the circle.

PROPOSITION II.

To inscribe a circle in a given triangle.



Let *PQR* be the given triangle; it is required to inscribe a circle within it.

Bisect ∠s *PQR*, *PRQ* by *QC*, *RC*, intersecting in *C*. (I. 8)

From *C* let fall *CD*, *CE*, *CF* perpendicular to *QR*, *RP*, *PQ*. (I. 13)

With *C* as centre and *CD* as radius describe a circle; it shall be the one required.

Because the $\angle$ s QDC, DQC are equal to the $\angle$ s QFC, FQC,

$\therefore\ \angle QCD = \angle QCF$; (I. 20)

also QC is common to the Δ s DQC, FQC,

$\therefore\ CD = CF$. (I. 6)

Similarly $CD = CE$.

$\therefore$ the circle passes through F and E.

Again, because QR is perpendicular to CD,

$\therefore$ QR touches the circle. (III. 3)

Similarly RP and PQ touch the circle.

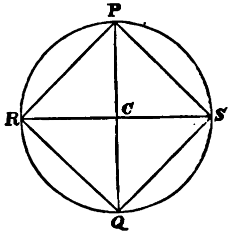
Wherefore a circle has been inscribed in the given triangle. Q.E.F.

DEFINITION.

A rectilineal figure is said to be **inscribed in a circle** when all its angular points are upon the circumference of the circle.

PROPOSITION III.

To inscribe a square in a given circle.



Let PRQ be the given circle; it is required to inscribe a square in it.

Draw the two diameters PCQ, RCS perpendicular to one another.

Join PS, SQ, QR, RP.

Then $PRQS$ shall be the square required.

Because PC, CR, and $\angle PCR$ are respectively equal to QC, CR, and $\angle QCR$, $\therefore PR = RQ$. (I. 4)

Similarly $RQ = QS$, and $QS = SP$.

$\therefore$ $PRQS$ is equilateral.

Again, since $\angle RPS$ is in a semicircle, $\therefore$ it is a right angle. (III. 6)

Similarly the other $\angle$s of $PRQS$ are right angles.

$\therefore$ $PRQS$ is a square.

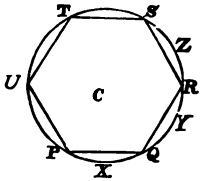
Wherefore a square has been inscribed in the given *circle.* Q.E.F.

DEFINITION.

A **regular hexagon** is a plane rectilineal figure bounded by six equal straight lines, and having its angles equal to one another.

PROPOSITION IV.

To inscribe a regular hexagon in a given circle.



Let *PQR* be the given circle; it is required to inscribe a regular hexagon in it.

Let the circumference be divided into six equal arcs *PXQ*, *QYR*, *RZS*, &c. (III. 11, Cor.)

Draw the chords *PQ*, *QR*, *RS*, &c.

Then shall *PQRSTU* be the regular hexagon required.

For if the figure were turned about *C*, so that *P* might coincide with the former position of *Q*,

and ∴ *Q* with that of *R*, *R* with that of *S*, and so on, since the arcs *PXQ*, *QYR*, &c., are all equal,

then the chord *PQ* would coincide with *QR*, and is ∴ = it:

similarly *QR* = *QS*, and so on.

∴ the hexagon is equilateral.

Also the arms of the $\angle PQR$ would fall where those of $\angle QRS$ were.

Hence $\angle PQR = \angle QRS$. Similarly $\angle QRS = \angle RST$; and so on.

∴ the hexagon is equiangular.

Wherefore a regular hexagon &c. Q.E.F.

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